

containing small amounts of free fatty acid, is much smaller than that of the undecomposed soap.

(3) The "surface activity" of free alkali in a soap solution is less than that of the same concentration of alkali in water.

(4) The addition of alkali to a soap solution increases the "surface activity" of the soap.

(5) This effect is much too large to be explained by the suppression of hydrolysis.

(6) It is suggested that the effect is partly due to an increase in the colloidal nature of the "semi-colloidal" soap solution.*

The Consumption of Carbon in the Electric Arc. No. III.—*The Anode Loss.*

By W. G. DUFFIELD, D.Sc., and MARY D. WALLER, B.Sc.

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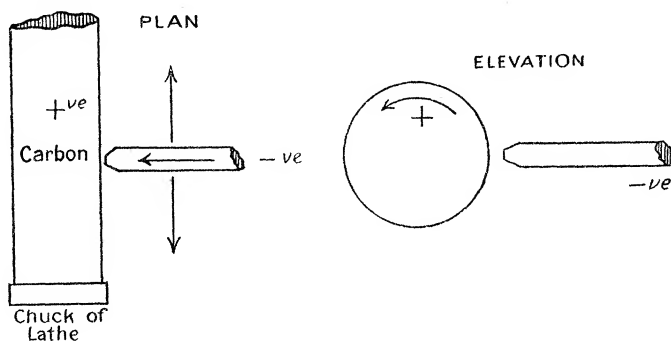
1. In a previous communication to the Royal Society† experiments conducted in the Physical Laboratory of University College, Reading, have been described, from which it appears that the rate of consumption of carbon from the cathode of a very short arc is such that the departure of one atom is accompanied by the transference between the poles of four electronic charges. The loss of weight of the anode is larger than this, on account of subsidiary combustion or evaporation occasioned by the high temperature of the crater.

An experiment has been described in the paper referred to which demonstrates the supreme importance of a hot cathode; the arc could be maintained with a hot cathode alone, but not with a hot anode alone. It was suspected in consequence of this that the anode consumption of carbon was unimportant, and the experiment was repeated in the following manner for the purpose of testing this.

* It may be pointed out that many of the facts relating to the effect of electrolytes on the adsorption of dyestuffs may be explained by the effects produced on the colloidal state of the dye, and on the potential difference between the fibre and the solution. See Harrison, "The Electrical Theory of Dyeing," 'Journal of the Society of Dyers and Colourists,' December, 1911.

† Duffield, 'Roy Soc. Proc.,' p. 122, *supra*.

2. The carbon anode, 20 cm. long and 1.8 cm. diameter, was mounted in a lathe so that it could be rotated about its axis, the bed of the lathe being earthed. The cathode carbon, 1 cm. diameter, was fixed at the same level in the saddle of the lathe, and could be moved along the lathe bed parallel to the anode, and also perpendicular to it for the purpose of adjusting the arc-length. This carbon was insulated from the lathe and connected through suitable resistances, ammeter, and voltmeter to the negative terminal of the 200-volt mains, the positive terminal of which was earthed. When an arc was started between the curved surface of the anode and the pointed end of the cathode the anode could be rotated at a high speed and the cathode moved rapidly backwards and forwards without extinguishing the arc, whereas when the polarity was reversed it at once blew out. This provided a means for obtaining an arc in which the anode remained comparatively cool because the crater did not have time to develop. The carbons were removable



and were weighed before and after each experiment, during which the current and arc-length were maintained as constant as possible. For observing the latter a lens was placed above the anode, and it projected an image of the arc upon a horizontal card supported higher up. As the carbon was not quite cylindrical there was a variation in the arc-length during the rotation, apart from the irregular lengthening due to the air currents produced by the rotation.

The carbons employed were solid and were not specially purified, because purification had not been found appreciably to affect the results in the previous experiments. They were, however, soaked in acid for some days, and washed with distilled water to free them from impurities.

The chief difficulty lay in the fact that moisture was driven from the carbons during the running of the arc, and on cooling moisture was absorbed from the atmosphere, causing the carbons to increase in weight with time—about 17 mgrm. in 13 hours for the heavy anode; the cathode gain was not

appreciable. This is chiefly a mechanical effect due to the deposit of water in the interstices of the carbon from the moist air of the laboratory. To obviate the difficulty of weighing, the carbon anode was always put into a brass cylinder immediately after each experiment, weighed in it and only removed when everything else was ready for the next experiment. The weighings were made not less than 25 minutes after the conclusion of the experiment, when the carbon was quite cold.

3. Table I gives the loss of weight occasioned by running arcs of different current strength for the times stated in the fourth column. The consumption of carbon per coulomb appears in columns 7 and 8, followed by columns representing the corresponding losses when the carbons were fixed (*loc. cit.*). The discrepancy in the cathode readings in the two cases, which is only marked in the 6-ampère arc, is chiefly due to the indeterminate arc-length in the present experiments, and to the arc being horizontal instead of vertical. The important thing to notice is that, whereas the anode loss is the greater in the fixed carbon arc, it is the less in the arc with rotating anode, also that in the most reliable experiments the ratios of anode loss with fixed poles to the anode loss with rotating anode are 17.6 to 0.25, 13.5 to 0.13, 12.8 to 0.33, and 10.8 to 0.36 respectively.

The lowest value for the loss from either pole in a normal arc occurred at the cathode when the arcs were indefinitely small, when 3.1×10^{-5} grm. were consumed for the passage of each coulomb of electricity (this is the value of the electrochemical equivalent of carbon if the element is quadrivalent). The above experiments demonstrate that the loss from the rotating anode is very much less even than this, and it is significant that, with increasing mastery of the technique of the experiment on the part of the observer (Miss Waller), the loss becomes smaller, the concluding observations involving total losses from the anode of only 3, 2, 8, and 13 mgrm. respectively. It would no doubt be possible to arrange that the heating of the anode should be still further reduced, but no good purpose would be served by achieving this; from the trend of the results the conclusion is irresistible that the anode loss of carbon is unimportant in the mechanism of the arc, and that the main function of the anode is to receive the carriers of the current produced by the essential process occurring at the surface of the cathode.

The usual rate of rotation of the anode was about 750 per minute; at this speed there is a considerable wind, which disturbs the arc and makes it longer than the shortest distance between the carbons. As the flame of the arc is sensible to this current of air, it is obvious that, in the space between the poles, some, at least, of the carriers are of atomic dimensions, though it

Table I.

Date.	Current.	Arc-length (minimum value).	Time.	Total loss.		Loss per coulomb.		Previous experiments. Fixed electrodes. Loss per coulomb. Arc-length, 1 mm.	
				Anode.	Cathode.	Anode.	Cathode.	Anode.	Cathode.
September 2.....	ampères. 4	mm. < 1·0	secs. 320	gm. 0·022	gm. —	gm. $1·72 \times 10^{-5}$	gm. —	gm.	
" 2.....	4	0·75	300	0·018	0·096	1·50	$8·0 \times 10^{-5}$		
" 2.....	4	0·8	320	0·022	0·116	1·72	8·8		
" 3.....	4	0·7	480	0·014	0·148	0·73	7·75		
" 3.....	4	0·7	314	0·012	0·092	0·96	7·05		
" 3.....	4	0·61	300	0·003	0·088	0·25	7·4	$17·6 \times 10^{-5}$	$8·3 \times 10^{-5}$
September 1.....	6	0·7	320	0·020	0·116	1·04	8·0		
" 1.....	6	0·7	300	0·021	0·125	1·16	8·8		
" 3.....	6	0·7	260	0·002	0·158	0·13	10·1	13·5*	6·5
September 2.....	8	0·7	305	0·009	0·163	0·39	8·9		
" 2.....	8	0·7	300	0·008	0·142	0·33	5·9	12·8	5·5
September 1.....	12	0·5	300	0·037	0·168	1·025	4·7		
" 3.....	12	0·7	300	0·014	0·160	0·39	4·44		
" 3.....	12	0·75	302	0·013	0·166	0·36	4·58	10·8*	5·3*

The experiments with arcs of the same current strength are given in the order in which they were made.

* Refer to values calculated from curves.

is not established in what proportion they are produced by ionisation or by direct ejection from the cathode. As the arc-length decreases there is a smaller deflection with rotation, and, using extremely small arcs, the deflection is scarcely appreciable, probably because the bulk of the current is then carried by electrons moving with high velocities.

In the normal type of arc the formation of the crater is accidental, and is not vital to the arc, though it is its most prominent and obvious feature. Two factors are responsible for the formation of the crater upon the anode, and not upon the cathode. One is the fact that electronic emission must occur at the anode as well as at the cathode once it is hot, and, as this constitutes a current against the main current in the arc-gap, an excess of ions in the opposite direction is required; these fall on to the pole and heat it. The other consideration is that negative electrons fall in great quantities upon the anode, but never upon the cathode, which consequently can only be bombarded by ions of atomic dimensions. Since electrons probably suffer less reduction in velocity in passing through the vapours of the arc than the gaseous atoms, their impacts occur with accelerated, and not with constant, velocity, and the heat developed is correspondingly greater.

4. In the following Table II the differences in potential between the poles are compared for arcs with rotating and fixed anodes. The former are the smaller, in spite of the fact that the effective arc-length with rotating anodes is probably even longer than is stated, for reasons already given; this should involve an increased, and not a diminished, potential difference.

Table II.

Current.	Potential difference.	
	Fixed poles.	Rotating anode.
ampères.	Arc-length, 0·5 mm.	Arc-length, 0·75 mm.
4	43	35
6	40	33
8	40	32·5
	Arc-length, 2·0 mm.	Arc-length, 2·2 mm.
3	48	40

This is accounted for by the reduction of electronic emission from the anode, which is comparatively cool when rotating. In the normal arc this emission is equivalent, as Pollock has suggested from Duddell's experiments, to a back E.M.F. When the anode is cool it is not necessary to supply a

forward E.M.F. to overcome it. The reduction in the electronic emission involves the potential difference between the poles in another way, because it diminishes the ionisation, and therefore increases the resistance of the vapour of the arc. For this reason the back E.M.F. at the anode is not quite the same as the difference between columns 2 and 3, namely, 7·5 volts.

A Collision Predictor.

By J. JOLY, Sc.D., F.R.S.

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In a recent paper in these Proceedings* I described a method by means of which the mariner is enabled to foretell risk of collision at sea, assuming that he knows the course and speed of each of the vessels concerned and that he is at intervals able to ascertain the distance separating them. For an account of the principles involved I must refer to my former paper. A simple geometrical construction enabling them to be applied is therein given. This construction informs the navigator whether there is risk of collision or not, and also enables him to ascertain the instant at which the danger is greatest.

However simple in character, it is probable that, to the average seaman, the operations involved in a geometrical construction would appear less practical than a mechanical or instrumental mode of interpreting the observations. It will be an additional attraction to an instrumental method if time be saved by its use. For the time available for the solution of the problem involved may be short. This might well be the case if the earlier signals for any reason escaped notice. Accordingly I have endeavoured to reduce the work of interpreting the observations to the simplest form. Of various types of apparatus for the interpretation of the geometrical principles involved, that which I now describe is, I believe, the easiest both to work and to construct.

The instrument consists (see fig. 1) of the half disc, *d*, which is graduated to compass divisions (and to degrees if desired); the points being named both for easterly and westerly bearings. Rotating stiffly around the centre of the circle, on a joint which admits of being clamped, two graduated limbs, *a* and *b*, are fixed. These limbs are mutually inclinable on a friction joint similar to that used on an ordinary folding rule. The limb *b* carries a sliding piece,

* P. 176, *supra*.